



Study on Mechanical Behavior of W–Cu Composites Fabricated via Powder Metallurgy

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Abstract: The research explores compositional dependence on physical and mechanical behavior output in tungsten-copper (W–Cu) composites made through powder metallurgical methods. The examination focused on W80Cu20, W70Cu30, and W60Cu40 among three compositions to determine density while also testing hardness and observing ultimate tensile strength (UTS). The experiments demonstrate that density drops at a constant rate as copper content increases in the materials while W80Cu20 reaches the greatest density value of 14.68 g/cm³ because tungsten produces its dominant impact. The tungsten inherent hardness diminishes because ductile copper opposes its natural resistance. The combination of W70Cu30 yields the highest ultimate tensile strength of 592 MPa because sintering densification reaches its peak, but W60Cu40 shows reduced strength at 470 MPa because copper adds excessive material ductility. Research indicates that W70Cu30 stands as the most effective composition combination because it delivers maximum tensile strength in addition to acceptable hardness while providing appropriate density requirements for structural applications. The research identifies the essential nature of composition design for W–Cu composites to produce superior mechanical and tribological properties that meet crucial demands in automotive and industrial applications.

Introduction

The W–Cu metal matrix composites link the extreme hardness and high strength properties of tungsten with copper's superior electrical and thermal characteristics. W–Cu composites serve in electrical contacts, heat sinks, and electrodes for electrical discharge machining (EDM) and aerospace components because they provide excellent thermal resistance along with mechanical reliability (Ho et al., 2008; Han et al., 2022; Zhang et al., 2023; Rashid et al., 2024). W–Cu composites develop specific physical and mechanical properties because their two-phase microstructure prevents solubility between elements, so each material preserves its own characteristics when finalising the composite structure (Zhou and Chen, 2016; Han et al., 2022; Zhang et al., 2023).

Fabrication of W–Cu composites requires an alternative method because the high melting point of

tungsten (3420°C) prevents its proper fusion with copper, which has a different melting temperature range. The most successful production technique for these composites exists through powder metallurgy (PM) according to Eessaa et al. (2023) and Dhanashekar et al. (2020). The powder metallurgy production method includes compacting tungsten and copper fine powders while raising pressure before applying high temperatures in a reducing atmosphere to complete the sintering process (Chen et al., 2017). The proper distribution of copper throughout the tungsten matrix becomes achievable through this manufacturing process which enables formation of strong inter-phase connections and precise creation of porosity. The addition of copper through skeleton infiltration of pre-sintered tungsten materials creates additional densification improvements (Liu et al., 2020).



Research investigations have established the ways in which material composition affects W–Cu composite properties. The research literature shows that tungsten content enhancements result in improved mechanical properties because tungsten exhibits intrinsic rigidity (Hou et al., 2023). The electrical and thermal properties enhance with increased copper levels, yet strength and hardness decline (Tejado et al., 2018). The tungsten-to-copper ratio must be optimized for any application because it defines how the properties balance out (Kim et al., 1998; Huang et al., 2018).

The researchers fabricated W–Cu composites through powder metallurgy methods using three compositions starting from W60Cu40 all the way to W80Cu20. The research included three compositions to demonstrate tungsten integration steps, which revealed increased tungsten's effects on material behaviour. The evaluation process involved density measurements and Vickers hardness testing and tensile strength evaluations of fabricated samples to decide their candidacy for structural and functional applications. This research investigates the mechanical impact of changing tungsten-to-copper ratios in the composite assessment to help engineers select and design materials for specific domains (Karwande et al., 2024).

Materials and Methods

Materials

The Cu–W or W–Cu composites represent engineered materials that consist of copper and tungsten phases which remain individually distinct since copper and tungsten demonstrate non-mixing behavior (Zhang et al., 2023). Such materials do not create a genuine alloy structure but display a microstructure design with tungsten particles embedded in a copper matrix which defines them as metal matrix composites (Stalin et al., 2021).

The composites unite the advantageous characteristics from their base metals. The unique composition of Cu–W composites enables multiple beneficial characteristics including outstanding thermal and electrical properties and superior workability and heat and molten metal protection abilities (Balwan & Dhemla, 2024). The combination of desired properties from W and Cu materials makes Cu–W composites work well in applications that need efficient thermal management and electrical connections (Verma et al., 2024).

The production procedure includes initial steps of shaping tungsten powder into desired forms through compacting followed by subsequent sintering of the

formed green body and then completing the process with copper melt infiltration (Chen et al., 2017). The final composite material permits production of different standard products such as rods, bars and sheets (Meignanamoorthy et al., 2021).

The performance characteristics of Cu–W composites exist mainly as a result of their chemical compounds. Composite products normally contain between 10–50 weight percent copper and the rest comprises tungsten material (Tejado et al., 2018). The lower copper ratios in compositions produce denser products with more substantial hardness levels alongside high electrical resistivity because tungsten prevails as the denser phase (Stalin et al., 2020).

Fabrication Process

Production of composites through powder metallurgy included these fundamental procedures:

#The combination of tungsten and copper powders occurred in high-energy ball milling over 4 hours to achieve even dispersion (Zhang et al., 2023).

#The hydraulic press applied 600 MPa pressure for forming uniaxial green compacts from blended powders (Liu et al., 2020).

#When hydrogen gas was used to stop oxidation in the compacts, Sintering operations occurred at 1200°C for 2 hours. The sintering phase used in liquid form triggered copper to infiltrate the tungsten materials' structure (Chen et al., 2017).

#Standard material sizes were created by processing the sintered items before mechanical and electrical testing was conducted (Zhou and Chen, 2016).

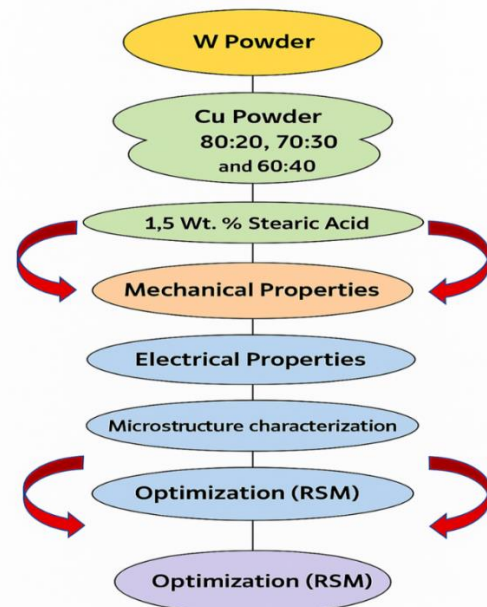


Figure 1. Schematic diagram for fabrication of W-Cu composite powders at different weight per cent of Cu 20, 30 and 40 wt.%.

Mechanical Testing

#Density Examination Used the Archimedes principle to weigh samples in air and water to determine their g/cm³ density value (Eessaa et al., 2023).

#Vickers hardness (HV) measurement required a microhardness tester under settings of 1 kgf load together with a 15-second dwell time (Han et al., 2022).

#The UTS measurement process took place on a universal testing machine which obeyed ASTM E8 standards when executing tensile tests at a 1 mm/min strain rate (Karwande et al., 2024).

Results analysis

The experimental data for density along with hardness and ultimate tensile strength (UTS) measurements of tungsten–copper (W–Cu) composites created through powder metallurgy with different W-Cu ratios of 80:20, 70:30, and 60:40 are analyzed in this section. Findings show that copper amounts affect the mechanical properties along with physical behavior patterns in these composites.

Density Analysis

The W-Cu composites fabricated under the study presented(a) direct correlation between compositional makeup and resulting density values (Table 1). The material W80Cu20 represented the density peak at 14.68 g/cm³, yet W60Cu40 reached the minimal density value at 12.16 g/cm³. The higher theoretical density value of tungsten at 19.25 g/cm³ when compared to copper at 8.96 g/cm³ causes this density relationship. The samples demonstrated successful consolidation through their relative density readings between 94.6% and 96.9%, which showed low levels of porosity.

Table 1. Density measurements of W-Cu composites.

Composition	Density (g/cm ³)
W80Cu20	14.68
W70Cu30	13.02
W60Cu40	12.16

Hardness Properties

The W80Cu20 alloy reached a maximum hardness level of 216 HB because it contained eight parts tungsten with two parts copper. Tungsten demonstrates high hardness because it is a refractory metal which dominates the composite composition thus increasing material hardness.

#The hardness of W70Cu30 (70% W, 30% Cu) equals 184 HB because adding more soft copper causes the composite to lose mechanical resistance and stiffness.

#The W60Cu40 proportion leads to the softest material with 138 HB hardness values because increasing copper results in material softening.

#Copper content within the metal matrix composite directly affects its hardness in accordance with the rule of mixtures, which describes mechanical properties based on phase volume distribution. The hardness properties of tungsten mainly influence the strength characteristics, yet copper minimises the material's overall hardness at higher concentrations.

Finally, the mechanical properties of W–Cu composites manifest an intense relationship to their composition levels, but fuller tungsten amounts better satisfy stiffness requirements.

Table 2. Hardness values of W-Cu composites.

Composition	Hardness (HB)
W80Cu20	216
W70Cu30	184
W60Cu40	138

Tensile Strength Performance

The W80Cu20 composite material achieves tensile strength of 587 MPa. The composite achieves a high UTS value because tungsten (W) dominates its composition and W naturally demonstrates high strength together with high modulus behavior. Tungsten proves to be an excellent material for load support and maintains structural rigidity within the composite structure. The 20% copper content within the material improves interfacial bonding and sintering densification quality during powder metallurgy processing despite being weaker and more flexible than tungsten material. The low melting point of copper works as a catalyst for liquid-phase sintering which enables better particle cohesion and results in more compact material. The small amount of copper in this mixture protects the material's strength because it does not weaken the solid structure through its weaker base components.

The W70Cu30 composite reaches a better UTS value at 592 MPa in comparison to W80Cu20. Initial doubt aside, the strengthened structure becomes understandable since more Cu was added to the material. The material's ductility, along with its toughness, is enhanced when it contains 30% copper because it allows stress to distribute evenly throughout the structure and prevents breakage. A benefit of adding Cu to the material is its ability to promote better sintering densification and grain boundary diffusion processes, which minimise internal void formation and enhance particle uniformity. This composition point of the microstructure has probably optimized its tensile strength by achieving an excellent balance between strength and ductility.

Table 3. Tensile properties of W-Cu composites.

Composition	UTS (MPa)
W80Cu20	587
W70Cu30	592
W60Cu40	470

The W60Cu40 composite shows a substantial UTS reduction to 470 MPa. The mechanical response of the material gets increasingly controlled by copper because of its excessive content, reaching 40%. Copper improves material ductility, yet its weaker strength than tungsten makes the composite more flexible. The excess copper in the material causes localised plastic deformation, which creates regions that are less effective in bearing loads in the tungsten structure. The composite turns into a predominantly copper-based metallic structure since tungsten reallocates its material into a fragmented pattern, thereby weakening tensile strength. Higher amounts of copper could create both thermal mismatch stresses and interfacial decohesion, which seriously damages the mechanical properties.

Discussions

The powder metallurgy fabricated W–Cu composites show their physical and mechanical properties adjust substantially based on their composition. This research shows that the relationship between tungsten and copper components becomes complex because the trends of density and hardness and ultimate tensile strength (UTS) vary.

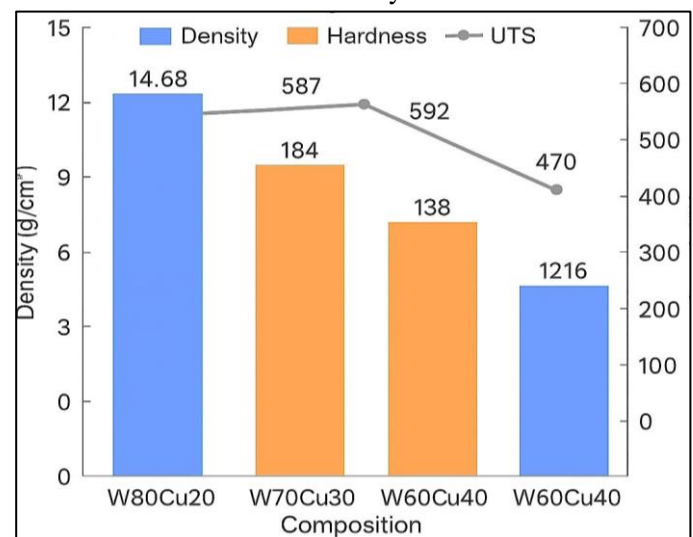
Densities decreased uniformly as copper levels increased because copper has a theoretical density value (8.96 g/cm³) that is lower than tungsten (19.25 g/cm³). The W80Cu20 mix reached the maximum density level at 14.68 g/cm³ and W60Cu40 showed the minimum density level at 12.16 g/cm³. The measurement validates that tungsten's substantial density fraction controls the final density while more copper reduces the substance's overall weight density. All specimens managed to retain high relative density values above 94% after sintering, demonstrating that powder compaction was successful and showed minimal documentation of porosity.

Analyses of material hardness showed that increased copper quantity in the material produced decreasing hardness results. W80Cu20 achieved its maximum hardness value at 216 HB since tungsten, as the primary constituent, offers natural material hardness. The material became less hard as the amount of copper grew through the phase transformation from W80Cu20 to W70Cu30 and ultimately W60Cu40. The W60Cu40 phase exhibited a minimum 138 HB hardness quantity. This trend's

mechanical properties match the mixtures' rule because they follow the volume fractions of each phase. When the proportions of copper increase in the mixture, the overall hardness and stiffness reduce, although ductility improves because copper is a softer material.

The behavior of tensile strength (UTS) results demonstrated complicated results. The W80Cu20 maintained its tensile strength at 587 MPa while it increased slightly to 592 MPa in W70Cu30 before dropping to 470 MPa for W60Cu40. The materials demonstrate their best combination of strength and ductility at the W : Cu ratio of 70:30. A higher 30% copper concentration in the material increased both the sintering densification level and grain boundary diffusion to boost mechanical interparticle bonding strength. The structural strength diminished as a result of excessive ductility when the concentration of copper reached 40%. The increased amount of copper in the material structure makes the tungsten framework more brittle and reduces its tolerance to bending under external forces.

These findings demonstrate that tungsten provides strength along with hardness but copper grants better sinterability plus ductility. You need to find the optimum blend of material components because this determines the best possible performance of structural frameworks. The W70Cu30 material combination stands out as a reasonable alternative between tensile strength excellence and suitable hardness and density characteristics.



Graph 1. Effect of Copper Content on Density, Hardness, and Ultimate Tensile Strength of W–Cu Composites.

#Density: The W80Cu20 composition achieves a maximum density value of 14.68 g/cm³ owing to its high tungsten concentration. The density decreases when copper percentages increase in the overall composition, from 13.02 g/cm³ for W70Cu30 to 12.16 g/cm³ for W60Cu40. The density pattern matches the

characteristics of natural metals since tungsten possesses much higher density than copper.

#Hardness: The specimens becoming progressively softer as the copper proportion in the composition increases. The former three materials resist deformation with increasing severity matching the order W80Cu20, W70Cu30 and W60Cu40 from highest to lowest hardness. The decreased hardness results from the effect of copper which provides a softening presence that reduces the mechanical properties of tungsten in the composite material structure.

#Ultimate Tensile Strength (UTS): The UTS behavior starts with a rising phase but proceeds toward a downward trend. The material W80Cu20 reaches 587 MPa UTS before W70Cu30 exhibits 592 MPa UTS. The test results indicate that using a certain level of copper during sintering both enhances the sintering process outcome and distributes load better. The UTS value in W60Cu40 falls to 470 MPa because excessive copper dilutes the structural durability through reduced load-bearing ability along with possible defects at interfaces.

Conclusions

The research established successful results for determining how different W–Cu ratios affect physical and mechanical characteristics through powder metallurgy fabrication processes. The research delivers the following important findings:

The density level of W–Cu composites becomes lower when copper content raises because tungsten exhibits a greater density than copper. Amongst the samples examined the W80Cu20 showed the greatest density level because tungsten possessed the most weight.

Hardness measurements demonstrate a downward pattern when using increasing levels of copper in the material. The tungsten fraction determines hardness rates but the declining values stem from the rising influence of ductile copper in the material structure.

Ultimate Tensile Strength (UTS) reached maximum value at the W70Cu30 composition indicating the composition that optimizes strength while maintaining ductility. UTS rises from W80Cu20 to W70Cu30 because enhanced bonding between particles together with balanced stress distribution occurs yet W60Cu40 shows a decline in these strengths because it weakens the framework and expands plastic behavior.

This research demonstrates that W–Cu composition optimization serves as the main factor to control the properties of W–Cu composites. The original research demonstrates that W70Cu30 presents the strongest

combination of tensile strength together with moderate hardness alongside acceptable density.

Conflict of interest

None

References

- B., Prakash, D., & Dhemla, P. (2024). Assessment of Cement Mortar Strength Mixed with Waste Copper Mine Tailings (CT) by Applying Gradient Boosting Regressor and Grid Search Optimization Machine Learning Approach. *International Journal of Experimental Research and Review*, 42, 183–198.
<https://doi.org/10.52756/ijerr.2024.v42.016>
- Chen, W., Shi, Y., Dong, L., Wang, L., Li, H., & Fu, Y. (2017). Infiltration sintering of WCu alloys from copper-coated tungsten composite powders for superior mechanical properties and arc-ablation resistance. *Journal of Alloys and Compounds*, 728, 196–205.
<https://doi.org/10.1016/J.JALLCOM.2017.08.164>
- Dhanashekar, M., Loganathan, P., Ayyanar, S., Mohan, S., & Sathish, T. (2020). Mechanical and wear behaviour of AA6061/SiC composites fabricated by powder metallurgy method. *Materials Today: Proceedings*, 21, 1008–1012.
<https://doi.org/10.1016/j.matpr.2019.10.052>
- Eessaa, A., Elkady, O., & El-Shamy, A. (2023). Powder metallurgy as a perfect technique for preparation of Cu–TiO₂ composite by identifying their microstructure and optical properties. *Scientific Reports*, 13. <https://doi.org/10.1038/s41598-023-33999-y>
- Han, Y., Li, S., Cao, Y., Li, S., Yang, G., Yu, B., Song, Z., & Wang, J. (2022). Mechanical Properties of Cu–W Interpenetrating-Phase Composites with Different W-Skeleton. *Metals*, 12(6), 903.
<https://doi.org/10.3390/met12060903>
- Ho, P. W., Li, Q. F., & Fuh, J. Y. H. (2008). Evaluation of W–Cu metal matrix composites produced by powder injection molding and liquid infiltration. *Materials Science and Engineering: A*, 485(1–2), 657–663.
<https://doi.org/10.1016/j.msea.2007.10.048>
- Hou, C., Lu, H., Zhao, Z., Huang, X., Han, T., Luan, J., Jiao, Z., Song, X., & Nie, Z. (2023). Performance of a Hierarchically Nanostructured W–Cu Composite Produced via Mediating Phase Separation. *Engineering*, 26, 173–184.
<https://doi.org/10.1016/j.eng.2022.09.017>

- Huang, Y., Zhou, X., Hua, N., Que, W., & Chen, W. (2018). High temperature friction and wear behavior of tungsten – copper alloys. *International Journal of Refractory Metals and Hard Materials*, 77, 105–112. <https://doi.org/10.1016/j.ijrmhm.2018.08.001>
- Karwande, R., Bhosle, S., & Keche, A. (2024). Improving Deposition Quality of Stellite Powder on Valve Seats by Optimized TIG Welding Parameters. *International Journal of Experimental Research and Review*, 45(Spl Vol), 70–82. <https://doi.org/10.52756/ijerr.2024.v45spl.006>
- Kim, J., Ryu, S., Kim, Y., & Moon, I. (1998). Densification behavior of mechanically alloyed W-Cu composite powders by the double rearrangement process. *Scripta Materialia*, 39, 669–676. [https://doi.org/10.1016/S1359-6462\(98\)00232-2](https://doi.org/10.1016/S1359-6462(98)00232-2)
- Liu, J., Wang, K., Chou, K., & Zhang, G. (2020). Fabrication of ultrafine W-Cu composite powders and its sintering behavior. *Journal of Materials Research and Technology*, 9, 2154–2163. <https://doi.org/10.1016/j.jmrt.2019.12.046>
- Meignanamoorthy, M., Ravichandran, M., Mohanavel, V., Afzal, A., Sathish, T., Alamri, S., Khan, S., & Saleel, C. (2021). Microstructure, Mechanical Properties, and Corrosion Behavior of Boron Carbide Reinforced Aluminum Alloy (Al-Fe-Si-Zn-Cu) Matrix Composites Produced via Powder Metallurgy Route. *Materials*, 14. <https://doi.org/10.3390/ma14154315>
- Rashid, A. B., Haque, M., Islam, S. M. M., Uddin Labib, K. M. R., & Chowdhury, P. (2024). Breaking Boundaries with Ceramic Matrix Composites: A Comprehensive Overview of Materials, Manufacturing Techniques, Transformative Applications, Recent Advancements, and Future Prospects. *Advances in Materials Science and Engineering*, 2024, 1–33. <https://doi.org/10.1155/2024/2112358>
- Stalin, B., Ravichandran, M., Karthick, A., Meignanamoorthy, M., Sudha, G. T., Karunakaran, S., & Bharani, M. (2021). Investigations on Microstructure, Mechanical, Thermal, and Tribological Behavior of Cu-MWCNT Composites Processed by Powder Metallurgy. *Journal of Nanomaterials*, 2021, 1–15. <https://doi.org/10.1155/2021/3913601>
- Stalin, B., Ravichandran, M., Sudha, G., Karthick, A., Prakash, K., Asirdason, A., & Saravanan, S. (2020). Effect of titanium diboride ceramic particles on mechanical and wear behaviour of Cu-10 wt% W alloy composites processed by P/M route. *Vacuum*, 109895. <https://doi.org/10.1016/j.vacuum.2020.109895>
- Tejado, E., Müller, A., You, J., & Pastor, J. (2018). The thermo-mechanical behaviour of W-Cu metal matrix composites for fusion heat sink applications: The influence of the Cu content. *Journal of Nuclear Materials*, 498, 468–475. <https://doi.org/10.1016/J.JNUCMAT.2017.08.020>
- Verma, D., Singh, B. P., Kumar, A., & Rizvi, S. A. H. (2024). Assessment of Surface Quality during EDM of AISI 4147 with Copper Tool. *International Journal of Experimental Research and Review*, 38, 173–181. <https://doi.org/10.52756/ijerr.2024.v38.016>
- Zhang, B., Yang, K., Huang, Z., & Wang, J. (2023). Recent Advances in W–Cu Composites: A Review on the Fabrication, Application, Property, Densification, and Strengthening Mechanism. *Advanced Engineering Materials*, 26(1). Portico. <https://doi.org/10.1002/adem.202301204>
- Zhou, Q., & Chen, P. (2016). Fabrication of W–Cu composite by shock consolidation of Cu-coated W powders. *Journal of Alloys and Compounds*, 657, 215–223. <https://doi.org/10.1016/J.JALLCOM.2015.10.057>

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